Hubbard Brook Experimental Forest

United States Department of Agriculture

PREPARED BY Forest Service

Northeastern Forest Experiment Station
NE-INF-71-86

COVER PHOTO:
Northeast corner of Hubbard Brook Experimental Forest. Foreground—Watershed 101 (12 ha) block clearcut in 1970; middle left—Watershed 4 (36 ha) strip cut in 1970, 1972, and 1974; middle right—Watershed 2 (16 ha) experimentally clearfelled in 1965 and treated with herbicides.

The Hubbard Brook Experimental Forest (HBEF) is a 3,160-hectare reserve dedicated to the long-term study of forest and stream ecosystems. Located in the White Mountain National Forest of New Hampshire, the HBEF was established in 1955 and is operated by the USDA Forest Service, Northeastern Forest Experiment Station. Beginning in 1963, the Forest Service, Dartmouth College, and later Yale and Cornell Universities and The New York Botanical Garden developed the Hubbard Brook Ecosystem Study. Cooperative efforts among many educational institutions, government agencies, foundations, and private industries continue to produce extensive information on the biology, geology, and chemistry of forest and freshwater ecosystems. Understanding gained from this research aids in the long-term management of natural resources for water supply, water quality, wildlife, timber yield, and sustained forest growth.

The Hubbard Brook Ecosystem Study

The small-watershed approach to nutrient cycling in ecosystems was pioneered at the Hubbard Brook Experimental Forest. The technique designates a watershed (catchment) as the basic unit for ecosystem study to determine inputs, outputs, and internal cycling of water, nutrients, and energy. Small watersheds (ranging from 12 to 76 hectares) in the HBEF have well-defined boundaries where the topographic divide coincides with the water divide. Measurements of streamflow on all watersheds over many years suggest that deep seepage is negligible, and that the bedrock is nearly watertight. Thus, precipitation enters the ecosystem and, after short periods of storage in the soil or snowpack, leaves as streamflow or evapotranspiration (water evaporated directly from leaves, soil, and snow). For small forested watersheds at the HBEF, the average annual hydrologic budget is:

Precipitation (131 cm) = Streamflow (82 cm or 63 percent) +
Evapotranspiration (49 cm or 37 percent)

Small watersheds are used in studies of nutrient cycling because of the close link between the movement of water and nutrients. Precipitation is a major source of sulfur and nitrogen. Weathering of bedrock and soil supplies dissolved calcium, potassium, and magnesium. These and other elements may accumulate in living and dead plant material and the soil and are cycled within the forest ecosystem. Losses occur as streamflow or

gases. Scientists at the HBEF can measure these sources, sinks, and fluxes of nutrients.

Six adjacent watersheds on a south-facing slope and two adjacent watersheds on a north-facing slope have been equipped to measure the amount and chemistry of water. Precipitation collectors are maintained and

Rainfall collector is sampled for chemical analysis.

sampled weekly at 21 locations. At the bottom of each watershed, the stream flows into a concrete stilling basin and over a V-notch weir, and for large watersheds, a metal flume and a V-notch weir work in tandem to

Gaging station for year-round monitoring of streamflow.

accommodate both high and low flows. Calibrated stage-height recorders measure streamflow throughout the year (heaters prevent ice in the V-notch from disrupting accurate measurements of streamflow in winter).

The small watersheds at the HBEF have relatively similar precipitation, geology, soils, streams, vegetation, and history. These features, along with the long-term records of precipitation and streamflow (more than 17 simultaneous years for the eight gaged watersheds), allow highly accurate predictions of streamflow. On the basis of precipitation and streamflow data from one watershed, scientists can predict streamflow for a nearby watershed within 5 percent of actual flow. This capability has made it possible to compare the impacts of various treatments on many watershed-ecosystem characteristics.

Long-term records of streamflow on the small watersheds provide a basis for experimental treatments. Selected parameters are monitored in paired watersheds for an appropriate number of months or years, and then

one of the watersheds is treated by cutting the forest, while another is maintained as a reference. Results observed from the treatment are compared with pretreatment data for the same watershed, and also with concurrent records for the untreated reference watershed. Thus, watersheds are used both to establish baseline information on undisturbed ecosystems and to evaluate experimentally the impacts of human-induced disturbances.

Site Characteristics

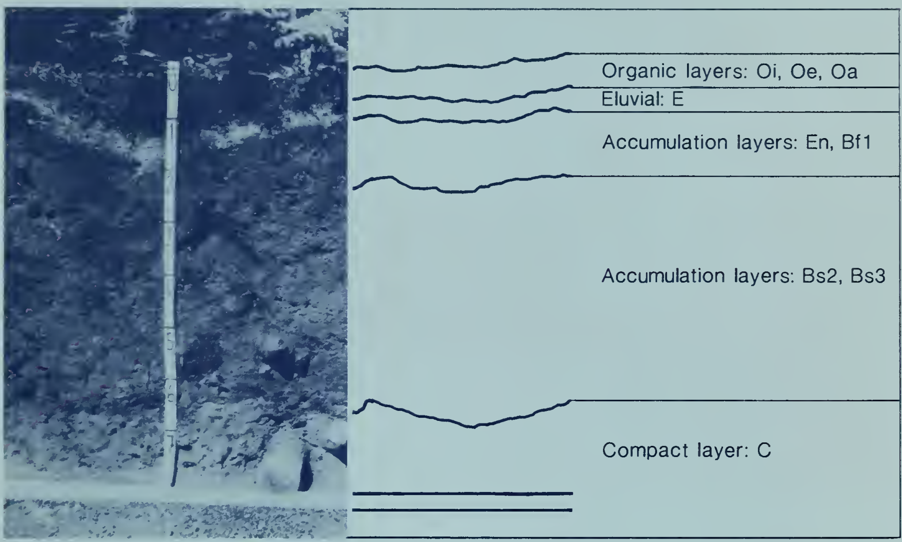
The Hubbard Brook Experimental Forest is located at 43°56′ N latitude and 71°45′ W longitude. The bowl-shaped drainage basin of Hubbard Brook ranges in elevation from 222 to 1,015 m at the top of Mount Kineo. Although the HBEF is only 116 km from the Atlantic Ocean, the climate is humid-continental with short, cool summers and long, cold winters. The average monthly air temperature is 19°C in July and -9°C in January. The average number of days without killing frost is 100 and the growing season for trees extends from May 15 (approximate time of full leaf development) to October 15 (leaf fall). Average annual precipitation is 131 cm per unit area of forest, with a winter snowpack of about 1.5 m. Average solar insolation is about 11.1 x 10^9 kcal/ha/yr. Of the solar radiation received by the Hubbard Brook Valley during the growing season, 15 percent is reflected, 41 percent is lost as heat, 42 percent is used in transpiration and evaporation in water, and 2 percent supports the biological functions of the entire ecosystem.

Geology and Soils

The bedrock of the Hubbard Brook Valley consists of highly metamorphosed mudstones and sandstones of the Littleton formation, and granitic rocks of the Kinsman formation. An unsorted mixture of boulders, stones, sand, silt, and clay was deposited over the bedrock by glaciers about 14,000 years ago. The soils formed by weathering of this glacial till are mostly well drained, acidic, and of a sandy loam texture. The topography is rough with pits and mounds caused by the uprooting of falling trees. Soils usually do not freeze during winter because of the thick layer of organic material and the snowpack. The soils are porous and there is little overland flow of water or surface erosion.

A common soil type in the Hubbard Brook Experimental Forest is the Becket series, a well-drained sandy loam soil with the following general characteristics: an organic layer (4 cm thick) of fresh (Oi horizon) and decomposing (Oe horizon) plant litter at the surface; a 5- to 7-cm-thick layer of partly and well-decomposed organic matter (Oa), pH 3.5; a leached,

light gray, fine sandy layer about 7 cm thick (E), pH 4.0; the subsoil, extending to a depth of about 65 cm, which is a dark, reddish-brown, fine sandy loam in the zone (upper 15 cm) of organic matter, iron, and aluminum accumulation (Bh and Bs 1), pH 4.5; a brownish-yellow, fine sandy loam in the next 23 cm (Bs2) pH 4.7; and a light olive-brown, fine sandy loam in the lower 15 cm (Bs3) pH 5.0. Below the Bs3 to a depth of 100 cm or more is a compact layer of very firm, grayish-brown, gravelly loam sand (C), pH 5.2.

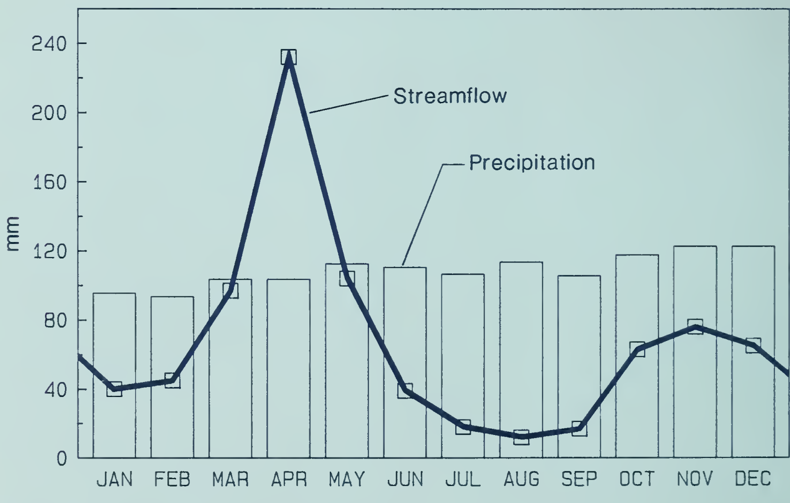


A typical soil developed from glacial till at the Hubbard Brook Experimental Forest.

Streams and Lakes

The Hubbard Brook Experimental Forest contains numerous headwater streams. Stream temperatures range from near 0°C to about 18°C. These headwater streams generally are acidic (pH 4.9) and high in dissolved oxygen, but low in organic carbon and nutrients which support aquatic life. Flows in the headwater streams range from zero during summer droughts to hundreds of cubic meters per hectare each day during storms or snowmelt. Between major storms or snowmelt, these streams carry only small amounts of particulate matter. Most of the 33 kg/ha/yr of sediment that are lost from a watershed are transported in the stream channel during brief periods of high flow.

Hubbard Brook in midwinter.



Precipitation/Streamflow Figure—Average monthly precipitation and streamflow for untreated Watershed 3.

Mirror Lake is adjacent to the HBEF, and is an integral part of the Ecosystem Study. It has an area of 15 ha, reaches a maximum depth of 11 m, and discharges into Hubbard Brook below the Experimental Forest. Water entering Mirror Lake comes from precipitation (22 percent) and surface runoff and groundwater (78 percent). Approximately 9 percent of the water leaving Mirror Lake is evaporated, 48 percent leaves in the outlet stream, and 43 percent is lost in deep seepage through glacial drift that forms the lower boundary of the lake. This freshwater ecosystem is nutrient-poor; the average pH is 6.0 to 6.4.

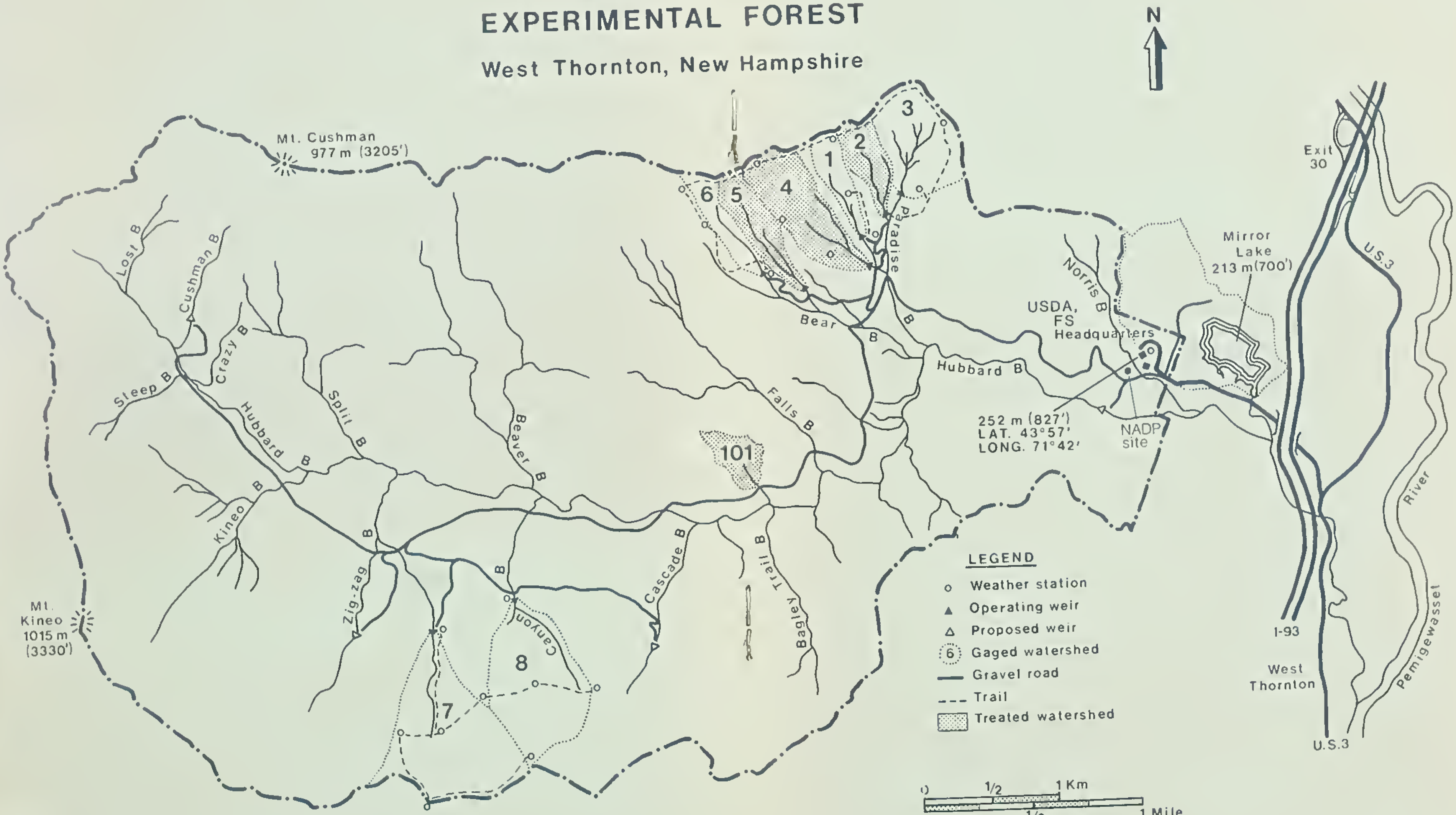
Mirror Lake—site of cooperative studies of aquatic-terrestrial linkages.

Plants

Major portions of the Hubbard Brook Experimental Forest, privately owned, at the time, were logged between 1910 and 1920. Since acquisition by the U.S. Government in 1920, stands of northern hardwoods (beech, sugar maple, and yellow birch) have developed; red spruce and balsam fir are found at higher elevations. Hobblebush and striped maple form a distinct understory, and Canada mayflower, trout lily, raspberry, and ferns typify the herbaceous groundcover. Algae are not abundant in the various tributaries of Hubbard Brook. Plants in Mirror Lake range from microscopic phytoplankton to sparse populations of macroscopic water lilies and lobelia.

HUBBARD BROOK EXPERIMENTAL FOREST

West Thornton, New Hampshire



Animals

Woodland animals include invertebrates (beetles, springtails, mites, bees, spiders, butterflies); birds (American redstarts, black-throated blue warblers, yellow-bellied sapsuckers, redtailed hawks, ruffed grouse); mammals (snowshoe hares, black bears, white-tailed deer, moose, red foxes, woodland jumping mice, beavers); reptiles (garter snakes, painted turtles); and amphibians (red-backed salamanders, toads). Streams support salamanders, larvae of the mayfly, stonefly, caddisfly, black fly, midge, and other insects. Mirror Lake contains midges, dragonflies, clams, zooplankton (rotifers, cladocerans, copepods), crayfish, salamanders, and fish (chain pickerel, smallmouth bass, yellow perch, brown bullhead, and white sucker).

Red fox—a common predator at the Hubbard Brook Experimental Forest.

Experimental Watershed Treatments

Four cutting operations and a variety of related studies have been carried out in the HBEF: 1) **Watershed 2** (16 ha): during the winter of 1965-66, all trees were felled and left on-site; this was followed by three summers of herbicide treatment to prevent the regrowth of vegetation. 2) **Watershed 101** (12 ha): during the autumn and winter of 1970, timber was removed in a commercial, block clearcut. 3) **Watershed 4** (36 ha): during the autumns of 1970, 1972, and 1974, progressive strips, 25 m wide, were cut and commercially valuable materials were removed. 4) **Watershed 5** (22 ha): during the autumn of 1983 through the summer of 1984, all trees larger than 10 cm in diameter at breast height were harvested by removal of whole trees (bole and tops).

Feller-buncher used in whole-tree clearcutting of Watershed 5.

Major Findings

Clearcutting of northern hardwood stands in the Hubbard Brook Experimental Forest has resulted in the following:

- An increase in temperature (as much as 6°C) at the soil surface and in streams.
- An increase in the moisture content of the soil.
- A maximum increase in streamflow of approximately 40 percent.
- Increased concentrations of nutrients, especially nitrate, in the soil solution subject to leaching loss or uptake by plants and microorganisms. An exception was sulfate, concentrations of which decreased.
- A 14-fold increase in concentrations of nitrate in stream water, a 3-fold increase in potassium, and a 2-fold increase in calcium after stem-only clearcutting.
- No appreciable increase in erosion and sedimentation.
- A decrease by half of the mass of organic matter in the forest floor (over the first 15 years).
- Rapid decomposition and fragmentation of slash (75 to 80 percent breakdown in the first 14 years).
- An increase in nitrification.
- Rapid growth of pin cherry and raspberry from seeds which had remained viable in the soil for decades; these pioneer plants conserve nutrients that otherwise might be leached from the site.

The magnitude of these changes was related to the type of disturbance:

- A strip cut (W4) resulted in smaller losses of nutrients by leaching to streams than a block clearcut (W101).
- Large losses of nutrients over several years resulted from clearfelling followed by herbicide treatments to delay regeneration of vegetation (W2).
- Increases in erosion caused by logging operations were minimized by careful planning, construction, and use of roads; by skidding over snowpack or dry ground; and by leaving buffer strips of uncut trees along streams.
- Natural regeneration flourished after commercial harvests; peak densities of pioneer species occurred around 2 years, and a closed canopy was formed by 10 years.
- At year 10, the stripcut (W4) had a more desirable mix of commercial species than the block clearcut (W101), with higher densities of yellow birch and sugar maple and lower densities of pin cherry.

Recovery of the northern hardwood forest ecosystem during the first decade after clearcutting is marked by the gradual return of water yield and stream water chemistry to precutting levels. Living biomass accumulates over 100 years or more. After an initial decrease, organic matter in the forest floor and dead wood also accumulate. With careful logging and continued use of 70- to 120-year intervals between harvests, clearcutting of northern hardwoods should not have adverse impacts on site nutrient capital, regeneration, or productivity, or lasting effects on water quality.

Other studies at the Hubbard Brook Experimental Forest include the following:

- The longest continuous record (since 1963) of precipitation chemistry in North America is maintained at the HBEF, and acid precipitation in North America was first documented and reported here. The average annual pH of precipitation varied somewhat between 1963 and 1986, but overall has remained at approximately pH 4.1. Decreasing annual concentrations of sulfate, calcium, and magnesium were observed during this period, whereas nitrate increased from 1964 to 1972. The origins and complex chemistry of these changes are being investigated. Known effects of atmospheric deposition on forests, streams, and lakes may range from beneficial (fertilization from nitrogen, phosphorus, calcium, and potassium) to adverse (toxicity from hydrogen ion, aluminum, or lead).
- Beginning in 1978 the Hubbard Brook Experimental Forest was designated as part of the National Atmospheric Deposition Program (NADP), a network of more than 150 sites in the United States for standardized collection and chemical analysis of precipitation.
- Composition of the woodland animal community is closely related to quality of the vegetation; for example, the decrease in numbers of least flycatchers, which were found in abundance in 1972-73 but were seldom seen after 1981, may reflect changes in tree species and canopy structure during that interval.
- The BROOK computer simulation model, developed and tested at the HBEF, predicts quantity of streamflow from the measurement of precipitation and air temperature.
- The JABOWA computer simulation model, also developed and tested at the HBEF, predicts forest growth following various harvesting operations.

- Managing the forest for protection from snowmelt floods seems unlikely in the Northeast. The timing of snowmelt in forested watersheds varies considerably according to the slope, aspect, elevation, and vegetation amount and type. Ownership of the land in many small parcels makes it difficult to design or implement general management schemes.
- Studies of other human activities on the HBEF and Mirror Lake ecosystems include those on the effects of regional air pollution on forest-lake-stream ecosystems; application of sewage sludge on forest growth and stream water quality; artificial acidification of streams (simulated acid rain) on stream chemistry and biology; development of lakeshore properties and road salt on water quality; and hunting on deer populations.

Facilities

A field headquarters provides space year round for offices, laboratory, conferences, living quarters, shop, garage, and storage. Additional laboratories and living space are available in nearby associated university-operated facilities. The White Mountain National Forest maintains 16 km of gravel roads, and a trail system provides access to outlying research installations, such as remote precipitation stations. Except for entry to the field headquarters, these roads and trails remain snow covered in winter, when travel in the forest is by foot, on snowshoes, or by motorized snow vehicle.

Forest Service headquarters at the Hubbard Brook Experimental Forest provides space for offices, laboratory, and residence.

Biosphere Reserve

The Hubbard Brook Experimental Forest is one of many sites established throughout the world as part of the United Nations, UNESCO, Man and the Biosphere Program. The Biosphere Reserves were selected to preserve representative ecosystems and to provide opportunities for long-term interdisciplinary research on the effects of humans on the biosphere. The Hubbard Brook site is the only Biosphere Reserve in the northeastern United States and is the sole representative of the northern hardwood ecosystem.

References

A yearly updated list of publications contributed by Hubbard Brook researchers is available from: Director, Institute of Ecosystem Studies of the New York Botanical Garden, Mary Flagler Cary Arboretum, Box AB, Millbrook, New York 12545; or, Project Leader, Water and Ecosystems, Northeastern Forest Experiment Station, Forestry Sciences Laboratory, P.O. Box 640, Durham, New Hampshire 03824.

Approximate Metric/English Equivalents

1 meter (m)	=	3.3 feet or 1.1 yards
1 kilometer (km)	=	5/8 mile
1 hectare (ha)	=	2.5 acres
1 liter (l)	=	1.1 quarts or 0.26 gallon
1 kilogram (kg)	=	2.2 pounds
1 kilogram/hectare	=	1.1 pounds/acre
° Celsius	=	5/9 x (° Fahrenheit –32)